USDA FOREST SERVICE
RESEARCH NOTE RM- 221

FOREST SERVICE
U.S. DEPARTMENT OF AGRICULTURE

ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

Pressure Bomb Measures Changes in Moisture Stress of Birchleaf Mountainmahogany after Partial Crown Removal

C. J. Campbell and Charles P. Pase[1]

The pressure-bomb technique detected highly significant changes in plant-moisture stress of mountainmahogany following 41 percent or more leaf-mass removal, but no significant reductions in stress when leaf mass removed was 36 percent or less.

Keywords: Pressure bomb, plant-moisture stress, *Cercocarpus betuloides*.

Modification of chaparral cover by burning, chemicals, or mechanical treatments is currently being tested on potential water-harvesting sites in the Southwest. A few public and private agencies are already manipulating vegetation over large areas, on the basis of present research findings (Pase and Ingebo 1965, Hibbert 1971).

Land managers usually attempt to reduce the original chaparral cover by 100 percent, but actual kill often is 60 percent or less. To achieve total kill or high cover reduction of the more undesirable shrubs and trees would substantially increase costs of equipment, labor, and/or chemicals. The temptation has been to treat more areas rather than to increase shrub kill to some as-yet-unknown optimum level. From a water-yield standpoint, however, is it advisable to seek moderate cover reduction over large areas, or to attempt complete vegetation control on smaller acreage? To answer this question explicitly is beyond the scope of this study; to do so, we would have to know the quantity of water residual plants use after partial crown removal or reduced competition. Evapotranspiration measurement under field conditions at best is subject to many errors. Some alternate, rapid method or "indicator" is needed to determine relative changes in plant-water status to help land and watershed managers evaluate local conditions and prescribe management alternatives. Our study was designed to determine: (1) if the pressure-bomb technique is suitable for monitoring changes in a plant's internal moisture stress following crown reduction, and (2) percent of crown removal necessary to affect the internal moisture stress and, by inference, soil-moisture conditions surrounding plant roots.

Literature

Considerable work has been reported in recent years on techniques for determining moisture stress in plants. Use of a pressure bomb (Scholander et al. 1964, 1965; Boyer 1967 a, b; Kaufman 1968) appears to be an effective field and laboratory method for determining an index of leaf-water potential and internal water stress of some plants. The technique consists of placing a leafy shoot, or single leaf, inside a steel chamber with the cut end exposed to the atmosphere. Pressure of dry nitrogen is increased within the chamber until xylem sap begins to bubble out from the cut end, at which time the pressure is recorded. This technique is particularly suited to field conditions because of rapidity of measurements, and low cost and dependability of equipment (Waring and Cleary 1967). Because the pressure needed

[1] *Botanist and Principal Plant Ecologist, respectively, Rocky Mountain Forest and Range Experiment Station, located at Tempe, in cooperation with Arizona State University; Station's central headquarters maintained at Fort Collins, in cooperation with Colorado State University.*

to force water from leaf cells to the cut xylem surface is basically a function of leaf-water potential (Boyer 1967b), predawn pressure-bomb readings can be considered as an index to soil-moisture availability within the root zone.

Bomb measurements are influenced by osmotic potential of the xylem sap, resistance to xylem movement of water, loss of water to voids in the xylem, the rate nitrogen is released into the pressure chamber, precision of the low-pressure gage, and elapsed time between twig removal and bomb reading. Even with these sources of error, a high degree of consistency between successive readings is usually characteristic of the bomb technique because the internal plant-water status tends to integrate the effects of myriad environmental factors. For example, if soil moisture is limiting but atmospheric stress is low, then the bomb reading will also be relatively low. A change of either parameter, however, will cause the bomb reading to change. Other environmental influences such as vapor-pressure deficit, wind, and temperature, plus phenology and physiology are integrated into every bomb reading.

Results of one study on Douglas-fir (Pseudotsuga menziesii) indicated soil-moisture stress readings on a single tree usually varied no more than ± 2.5 atmospheres. Under such conditions, readings between trees may vary 10 atmospheres (Waring and Cleary 1967). However, bomb data are not repeatable with the same degree of consistency within and among all species; therefore, a precursor to any "bomb" study is species selection.

Figure 1.--Using a pressure chamber to determine xylem moisture tension and by inference, internal moisture stress of a chaparral shrub.

Methods

The pressure-chamber technique was used in our studies to determine diurnal changes in moisture stress as a result of crown reduction (fig. 1). Ten mature birchleaf mountainmahogany (Cercocarpus betuloides Nutt.) shrubs between 7 and 10 feet tall were selected on an upland granitic soil on the Three Bar watersheds in central Arizona. Plants were rather uniformly spaced between 10 and 15 feet from codominant species of shrub live oak (Quercus turbinella Greene). Two sets of "calibration" bomb readings were taken on all 10 mountainmahogany shrubs on June 13 and 24, 1968, before the summer monsoon season began, to determine relationship between controls and plants to be treated (fig. 2). Each set consisted of several independent readings under predawn, afternoon, and night conditions on each shrub. During each "run" duplicate measurements were made on each plant. On July 25, crown mass was reduced by clipping stems at the root crown on random pairs of plants by an estimated 20, 40, 60, and 80 percent. One pair was left undisturbed as a control. Stems and leaves were ovendried and weighed.

After a 2-week period for the treated plants to become stabilized, bomb readings were taken throughout several 24-hour periods for 5 months from all 10 plants. Residual crowns were then clipped and weighed on December 10, 1968. Actual leaf-mass reductions were found to be 22, 36, 41, and 66 percent; crown-mass reductions including stems were 23, 39, 49, and 69 percent. Regrowth rates of treated and control plants were not determined, but observations indicated little differences in regrowth between treatment types, perhaps because of the unusually dry conditions.

Leaf subsamples were taken from harvested plants to determine leaf area-to-weight ratios. The mean leaf area-to-weight ratio found was 49.5 ± 4 cm^2/gm. The consistency of the data indicated leaf area also could be used to evaluate treatment effects on mountainmahogany in conjunction with bomb data.

Water content of turgid leaves was initially taken to determine plant-water status sequential to bomb readings. Leaves were floated on water and maintained at a constant temperature until the water deficit existing at the time of sampling was eliminated. However, there was no statistical correlation between plant-moisture stress and leaf water content. Bomb values reflect small changes in environmental stresses on a plant within minutes; however, a degree of equilibrium is unlikely to occur until well into the night. Conversely, leaf water content measurements are insensitive to small changes in environmental stress.

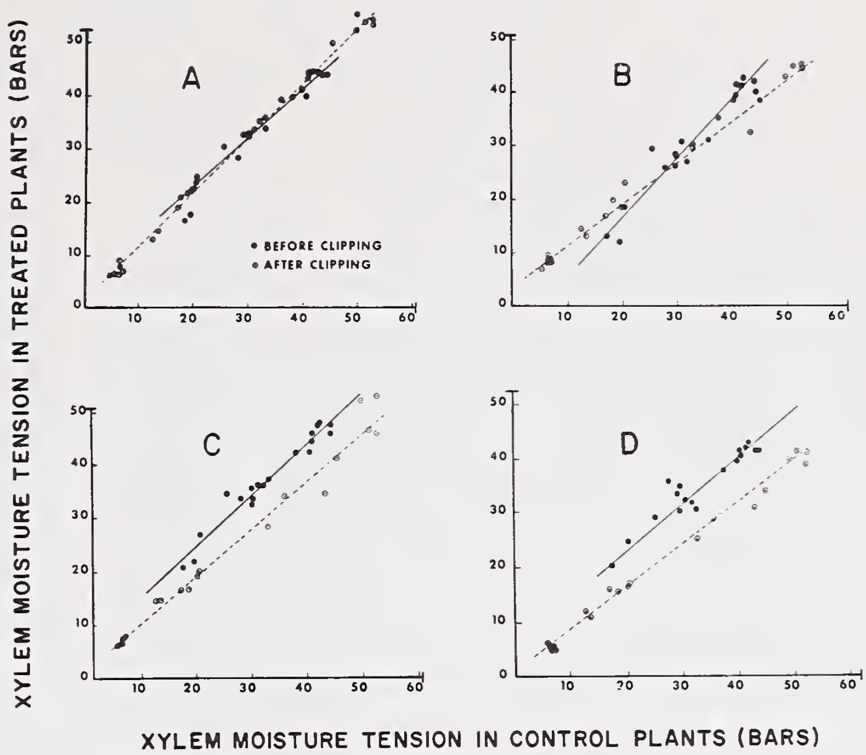

Figure 2.--Moisture tensions between two control plants, and plants with leaf mass reduced: A, 22; B, 36; C, 41; and D, 66 percent.

When mountainmahogany is under high stress, elapsed time between twig removal and the bomb reading is a very important source of error. In this study, therefore, we standardized a 1-minute lapse between twig removal and beginning of pressure application, regardless of anticipated plant stress. To eliminate other sources of mechanical errors, we preset the nitrogen inflow valve at 5 pounds per second, and used test gages with a precision of ± 2 pounds to indicate applied pressure.

Results and Discussion

The highest plant-moisture tension (55 bars) was recorded at midafternoon, but this value decreased to approximately 30 bars before midnight where it remained until sunup the following morning. Typically, the plant-moisture tension became stabilized by midnight. The soil-moisture demand determined the rate that tension decreased from late afternoon until midnight. The more crown removed, the faster the plant tension decreased from late afternoon until evening. Predawn bomb readings throughout the study period indicated a slight but not appreciable difference in available soil water between treated and untreated plants. Evidently, soil-water storage diurnally replenished these deep-rooted plants' demand for water throughout the study period.

The soil on the study site is Barkerville loamy coarse sand; it is nearly structureless, with decomposed and weathered coarse-grained granite extending to great depth. Regolith depths commonly exist to 40 feet as determined by seismic soundings. A 13-foot-deep soil trench near the study site indicated chaparral plant roots penetrate beyond this depth, where they are mostly confined to joint planes and crevices in the weathered granite. Road cuts indicate roots of these same chaparral species frequently penetrate to 30 feet. Consequently, relatively shallow soil-moisture measurements serve as indicators of soil-moisture storage in any given column, but do not necessarily indicate the source or quantity of water available to any particular plant or community. Soil-moisture values are also difficult to evaluate in terms of plant-water requirements because water requirements and use change with respect to plant growth cycles and environments. Also, and just as important, water limiting to one plant or species may be adequate for survival and growth of another. Plant-moisture stress reflects this unapparent discrepancy between the amount of soil moisture and plant-water demand, whereas soil-moisture measurements do not. The possible correlation between soil moisture and plant-moisture stress is being investigated in a later study.

Moisture tension was reduced in an "S" shaped curve following reductions expressed

in either leaf or total crown mass of mountainmahogany (fig. 3). Plant-moisture stress showed the greatest rate of decrease when leaf or crown mass was reduced between 30 and 50 percent. Plant-tension reduction following leaf-mass removal above 70 percent cannot definitively be determined, but it appears from figure 2 that plant tensions would be reduced approximately 9 to 10 bars and no more.

When day and night data before and after treatment are compared by a regression analysis, plants with 22 percent leaf mass removed had an actual average tension of 23.7 bars. Without treatment these plants would have had a predicted 24.3 bars average tension. The treatment effects on moisture tension were nonsignificant. Predicted changes in plant-moisture tensions are based on bomb data collected on all plants during the calibration period.

Plants with 36 percent leaf mass removed had 30.4 bars average tension, compared to a predicted tension of 33.2 bars if the treatment had not been performed. This reduction in tension indicated a highly significant change occurred following treatment, but insufficient data during the calibrating period prevent firm conclusions (fig. 2).

After a 41 percent leaf-mass reduction, post-treatment tensions differed highly significantly from a predicted 26.3 bars to an actual 20.6 bars. Even more obvious is the change in plant-moisture tension after 66 percent of leaf mass is removed (fig. 2D). Predicted tensions of the plants would have averaged 26.3 bars if no treatment had occurred; actual tensions averaged 17.8 bars — a decrease of about 8 bars.

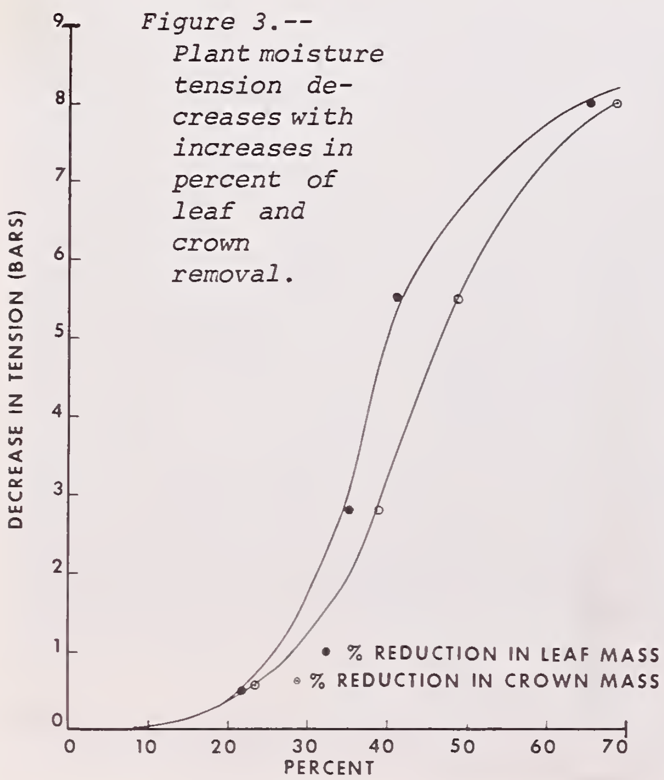

Figure 3.--Plant moisture tension decreases with increases in percent of leaf and crown removal.

From these data it seems reasonable to assume treatments that reduce leaf mass of mountainmahogany plants by about 35 percent do not measurably influence plant-water relationships. Our data indicate but do not necessarily prove that, in areas where 40 to 70 percent of the shrub crown mass has been removed, residual plants have lower moisture stress, probably because demand for soil water is reduced. Thus, total water use of the plant is probably less than before treatment, simply because of reduced evaporative leaf surfaces. We can logically assume soil moisture is more available in the immediate vicinity of these plant roots. In our study areas where competitive species were not removed, root systems of surrounding plants probably withdrew soil water normally removed by the treated mountainmahogany.

Literature Cited

Boyer, J. S.
1967a. Leaf water potentials measured with a pressure chamber. Plant Physiol. 42: 133-137.

____
1967b. Matric potentials of leaves. Plant Physiol. 42: 213-217.

Hibbert, Alden R.
1971. Increases in streamflow after converting chaparral to grass. Water Resour. Res. 7: 71-80.

Kaufmann, M. R.
1968. Evaluation of the pressure chamber technique for estimating plant water potential of forest tree species. Forest Sci. 14: 369-374.

Pase, C. P., and P. A. Ingebo.
1965. Burned chaparral to grass; early effects on water and sediment yields from two granitic soil watersheds in Arizona. Ariz. Watershed Symp. [Tempe, Ariz., Sept. 1965] Proc. 9: 8-11.

Scholander, P. F., H. T. Hammel, E. A. Hemmingsen, and E. D. Bradstreet.
1964. Hydrostatic pressure and osmotic potential in leaves of mangroves and some other plants. Natl. Acad. Sci. Proc. 52: 119-125.

________, H. T. Hammel, E. D. Bradstreet, and E. A. Hemmingsen.
1965. Sap pressure in vascular plants. Science 148: 339-346.

Waring, R. H., and B. D. Cleary.
1967. Plant moisture stress: evaluation by pressure bomb. Science 155: 1248-1254.